Chapter 3 - GPS Data Collection Description and Validation

The first step toward the analysis of accuracy and reliability of AVI system was to identify a suitable benchmark for measuring AVI system performance. GPS was chosen because of its ability to provide up-to-the-second position, speed and time measurements. This chapter describes the GPS units used in this evaluation exercise along with how the fidelity of the GPS travel times was evaluated. For validation purposes, a set of five GPS runs performed in March of 1998 by Texas Transportation Institute (TTI) employees was acquired and tested for accuracy. In addition, this chapter discusses the data collection performed for the AVI accuracy and reliability analysis.

3.1 Description of GPS Units

The GPS units used for this study were the Trimble Placer 400 GPS (Figure 3.1) model, which is specified to have a steady-state (with differential) position accuracy of 2-5 meters and a steady-state velocity accuracy of 0.1 meters per second. Latitude, longitude, day of the week, UTC time (Universal Coordinate Time, formerly known as Greenwich Mean Time), speed (mph) and direction are logged to a file each second by the GPS unit. In addition, each unit is equipped with a keypad with which the user can generate a "User Flag" to mark specific logged entries as they occur.

Figure 3.1 – Trimble Placer 400 GPS Unit

3.2 March 1998 Data Collection Overview

Prior to collecting and evaluating any AVI data, the GPS units were first tested for accuracy and repeatability. In doing so, the Virginia Tech Center for Transportation Research acquired five (5) GPS data files from TTI's Transguide personnel. The data files were created during morning and evening rush hour drive tests along a 2.20-mile stretch of I-35 in the northeast section of San Antonio between Loop I-410 and Outer Loop S.R. 1604. The location of the test runs is circled in Figure 3.2.

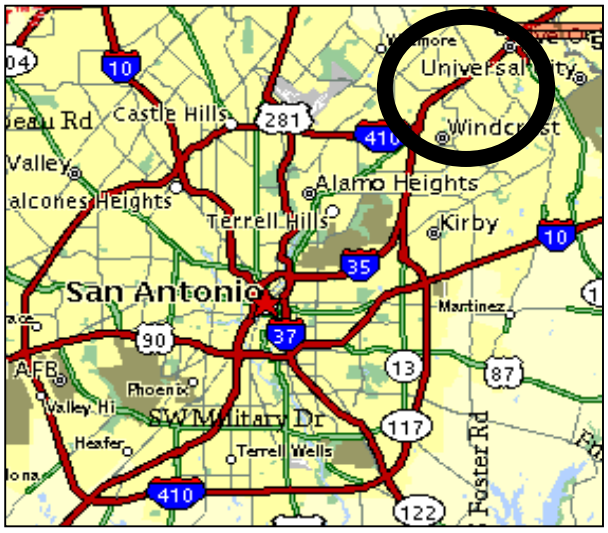

Figure 3.2 - Location of GPS Runs Performed by TTI (March 1998)
(source: http://www.mapquest.com/**)**

A tabular summary of the times and dates of the runs is given in Table 3.1.

Table 3.1 – Summary of GPS Test Runs Used to Evaluate GPS Units

SOUTHBOUND RUNS PM RUSH HOUR		**NORTHBOUND RUNS AM RUSH HOUR**	
DATE	**# OF RUNS**	**DATE**	**# OF RUNS**
3/4/98	1	3/3/98	1
3/5/98	1	3/5/98	1
3/6/98	1	- -	- -

3.2.1 Validation of GPS Data Fidelity

To validate the fidelity of the GPS units, a qualitative graphical analysis was first performed. In addition, a Root Mean Square Error (RMSE) analysis and a correlation analysis were performed to further quantify the fidelity of the GPS data.

3.2.1.1 Qualitative Analysis of GPS Data Fidelity

In validating the spatial accuracy of the GPS data, the first step was to plot the latitudinal and longitudinal coordinates of separate, overlapping trips on the same graph. This step was taken to obtain a visual, qualitative assessment of the general repeatability of the data. In doing so, the graph showed a very close correlation for both northbound and southbound trips on I-35. The graph showing the comparison of northbound trips 1 and 6 is illustrated in Figure 3.3.

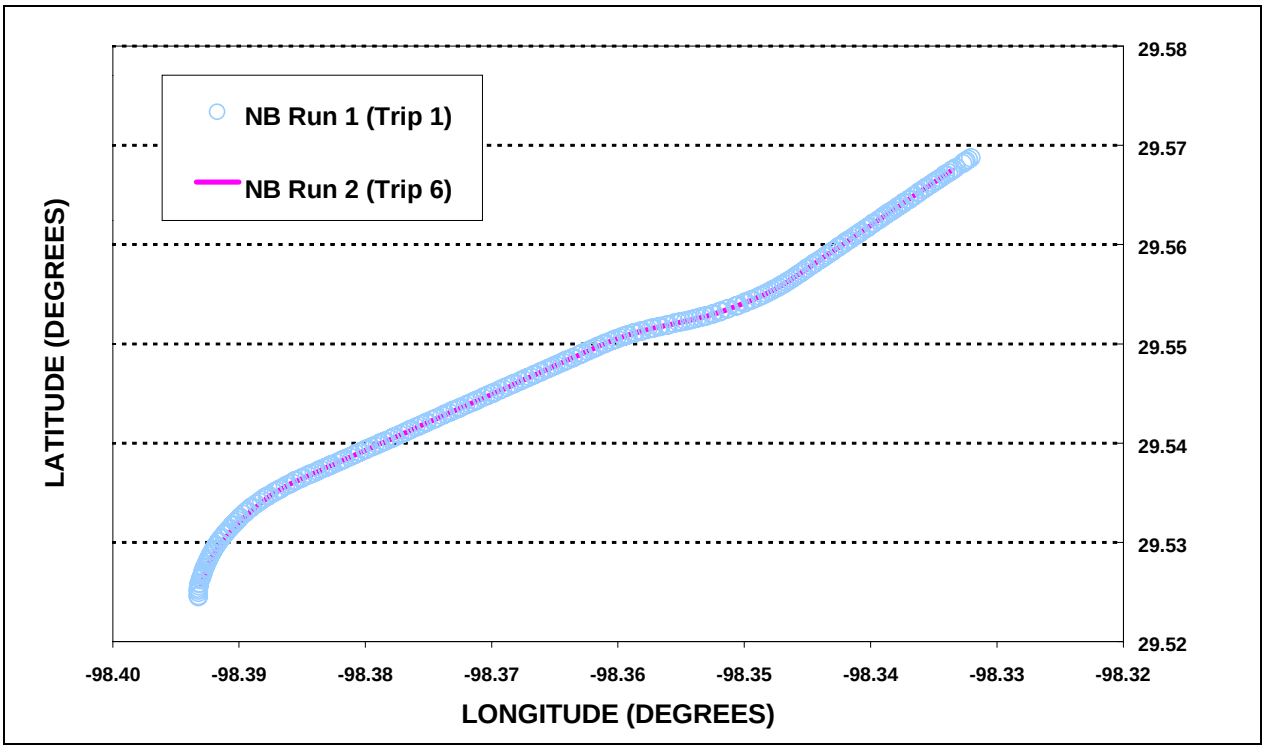

Figure 3.3 – Visual Assessment of Repeatability of GPS Runs

In creating these plots, it becomes clear that the units show some measure of repeatability given that the plots of the two similar trips appear to overlap completely.

3.2.1.2 Quantitative Analysis of GPS Data Fidelity

Given the extremely small scale in Figure 3.3 above (one tick mark of 0.01 degrees is equal to roughly 1 km for both latitude and longitude), it was recognized that a *quantitative* assessment of the spatial repeatability of runs was needed. The quantitative analysis methodology and results are reported in this section.

3.2.1.2.1 Quantitative Analysis Methodology

The first step in the quantitative analysis methodology was to edit the GPS trip files into links with the same beginning and ending GPS locations. The links on both the northbound and southbound corridors were defined by the locations of AVI readers 50 and 47, mounted directly above the highway. GPS coordinates for these AVI sites were provided by the Texas Transportation Institute (TTI) and are shown below in Table 3.2.

Table 3.2 – GPS Coordinate Locations for AVI Sites 50 & 47

AVI SITE #	LATITUDINAL COORDINATE	LONGITUDINAL COORDINATE
47	29.531590	-98.390529
50	29.556040	-98.346949

Because the GPS units log the probe vehicle's position only once every second, it was unlikely that any trip file would contain the precise location of the start and end nodes provided by TTI. Such was the case with the five files provided. As a result, start and end locations for each trip were determined by finding the latitudinal coordinate pairs of each GPS file that *bounded* the latitudinal coordinates of the respective AVI reader sites. The "outermost" coordinates were then used as the bounds. In effect, the trip files were cropped to start and end one reading before and after the respective beginning and end nodes (AVI reader sites 47 and 50) of the actual link. With the GPS trips pared down to links, conversion factors were applied to the latitudinal and longitudinal coordinates to convert them into metric distances as indicated in Table 3.3.

Table 3.3 – Conversion Factors for GPS x Metric Conversions

Multiply	By	To Obtain
1^{o} Latitude	111,000	Meters (latitude)
1^{o} Longitude	82,000	Meters (longitude)

Using the conversion factors in Table 3.3, the GPS coordinates were converted to metric distances with the starting coordinates for each trip set equal to 0.0 m latitude, 0.0 m longitude. A correlation analysis was then performed on the metric trip coordinates. In quantitatively

analyzing the GPS data, it was decided to perform RMSE analyses and correlation analyses on pairs of similar runs. Since there were only two northbound runs to analyze, only one analysis was performed for the northbound readings. However, with three sets of southbound data available, three sets of two pairs were analyzed. The similar files were then run two-at-a-time through a computer program, which extracted by interpolation the GPS longitudinal and latitudinal readings at 100-meter longitudinal intervals along the trips. Given that the trips were approximately 3500 meters in longitudinal length, a total of 35 GPS locations were extracted for each trip. The points for each file were then compared to the same points from each of the other like files to examine the accuracy of the units throughout the course of each trip.

3.2.1.2.2 Quantitative Analysis Results

A RMSE analysis for both north- and southbound trips revealed that the GPS units demonstrated a very high spatial repeatability between trips. In other words, the hundred-meter points interpolated from the GPS data for similar trips fell very close to one another for both the north- and southbound scenarios. In addition, a correlation analysis of like sets of north- and southbound trips yielded very similar results: there was an extremely high correlation in the progression of 100-meter points from trip to trip. The numerical results of both the RMSE analysis and the correlation analysis are summarized in Table 3.4:

Table 3.4 – RMSE and Correlation Analysis Results of GPS Runs

DIRECTION	# OF RUNS	AVERAGE RMS ERROR (m)	AVERAGE CORRELATION COEFFICIENT
Northbound	2	1.19	0.99998
Southbound	3	1.74	0.99997

The results for the average RMSE for both northbound and southbound runs were found to be less than two meters for each case. This low error level indicates that the GPS units were highly successful in repeating the same position data for similar runs. In addition, the change of positions from point to point for similar runs is shown to be repeated with an extremely high level of reliability, given the average correlation coefficients that are nearly equal to 1.0.

These results adequately support the conclusion that the Trimble Placer 400 GPS units are a suitable benchmark with which to test the accuracy of San Antonio's AVI system.

3.3 June 1998 Data Collection Overview

The second data collection exercise in San Antonio took place from June 9 through June 12 and covered a freeway section with loop detectors and AVI readers, an arterial with AVI readers, and a set of coordinated and uncoordinated signalized arterials. The original intent of the data collection was to gather useful information from which to compare the accuracy of AVI, loop data and theoretical travel time estimates. Most importantly, the data would be used to evaluate how the accuracy of travel times are impacted by the level of congestion, and how the accuracy of AVI tags varies across facility types (freeway versus arterial). All data were collected using Trimble Placer GPS 400 units identical to the unit used in the March data validation. The GPS data were then downloaded to a laptop computer and converted to database format (.dbf) by TTI personnel before being turned over to the VTCTR for analysis. Data collection runs on all routes were scheduled to capture AM and PM traffic peaks (6:30 AM – 9 AM, 3:30 PM – 6:00 PM) as well as midday off-peak (11 AM – 1 PM) traffic conditions.

3.3.1 June Data Collection – Freeway Section

The data collection route on I-35/410 covered four AVI reader sites (42, 43, 44 and 45) as illustrated in Figure 3.3.

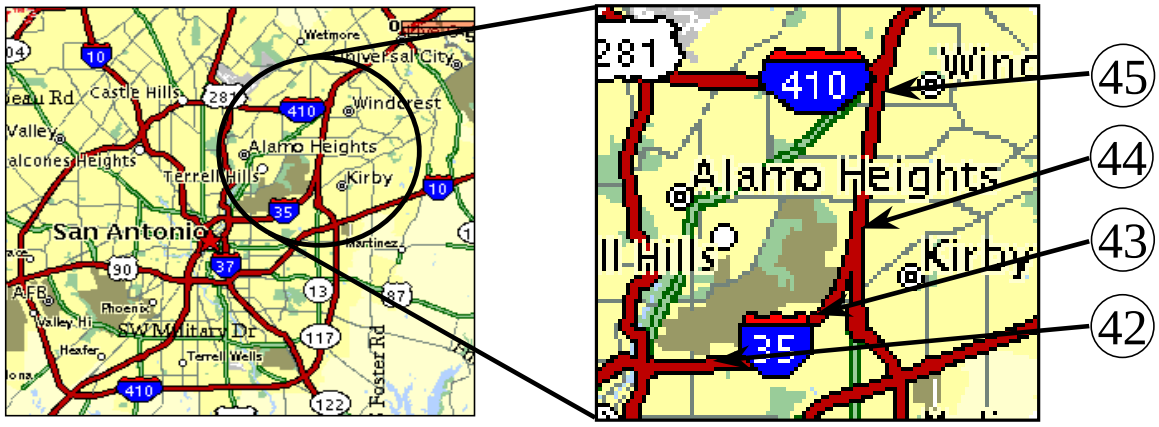

Figure 3.4 – Freeway AVI Data Collection Route: I-35 & I-410/35
(source: http://www.mapquest.com/**)**

With exception of the trips on 6/9/98, the extent of the runs was from the Fair Avenue exit (Exit 138) on I-37 to the Weidner Blvd exit (Exit 168) on I-35. Those taken on 6/9/98 extended only as far north on I-35/410 as the Starlight Exit (Exit 167), one exit south of Weidner Blvd. This AVI section was chosen because it spans a weaving section that would generate recurring congestion in which AVI performance could be analyzed. This weaving section is described in more detail in Chapter 5.

The test vehicle that was utilized to collect data was a Plymouth Neon equipped with an AVI transponder tag in order to register the trips in the AVI database. The AVI tag reads generated by the test vehicle would later be analyzed in comparison with the GPS travel times.

The AM peak runs were performed starting from between 6:30 and 7:00 am each morning to 9:00 am. On 6/9/98, the first few runs were used to establish the locations of the mileposts and the approximate half-mile locations between them. In addition, the beginning and endpoints of the trips were marked along with the beginning and end of the exit ramp transitions connecting I-35/410 and I-37. Owing to a misunderstanding of the highway geometry, the first day's runs included only AVI readers 42, 43 and 44. This oversight was corrected on the runs performed on 6/10/98 and 6/11/98 as the trips were extended one extra exit to the north to accommodate AVI reader # 45.

Beginning on 6/10/98, all AVI readers for each trip were marked using the GPS unit's User Flag option by pressing 'p' on the keyboard to indicate the passage of our test probe vehicle beneath an AVI antenna. A sample display of the GPS output with user inputs to mark reader locations is shown in Table 3.5.

Table 3.5 – Sample GPS Unit Display With User Flags to Mark AVI Antenna Locations

LATITUDE	_LONGITUDE	_DAY	_TIME	_SPEED_(MP	_DIRECTION	_GPS_RATIN	_USER_FLAG
29.481190	-98.403869	4	07:08:32	48	-169	1	
29.481000	-98.403909	4	07:08:33	48	-169	1	
29.480810	-98.403949	4	07:08:34	48	-169	1	p
29.480710	-98.403969	4	07:08:35	48	-169	1	
29.480420	-98.404029	4	07:08:36	47	-169	1	
:	:	:	:	:	:	:	
:	:	:	:	:	:	:	
:	:	:	:	:	:	:	
29.452250	-98.419589	4	07:11:01	53	-116	1	
29.452150	-98.419809	4	07:11:02	52	-116	1	
29.452060	-98.420019	4	07:11:03	52	-115	1	p
29.451970	-98.420239	4	07:11:04	52	-115	1	
29.451690	-98.420899	4	07:11:07	52	-115	1	

3.3.2 June Data Collection – Arterial Section

The arterial section covered during the GPS runs consisted of the portion of Fredericksburg Road from Huebner Road south to I-410, spanning AVI reader sites 15, 16 and 17 as illustrated in Figure 3.4.

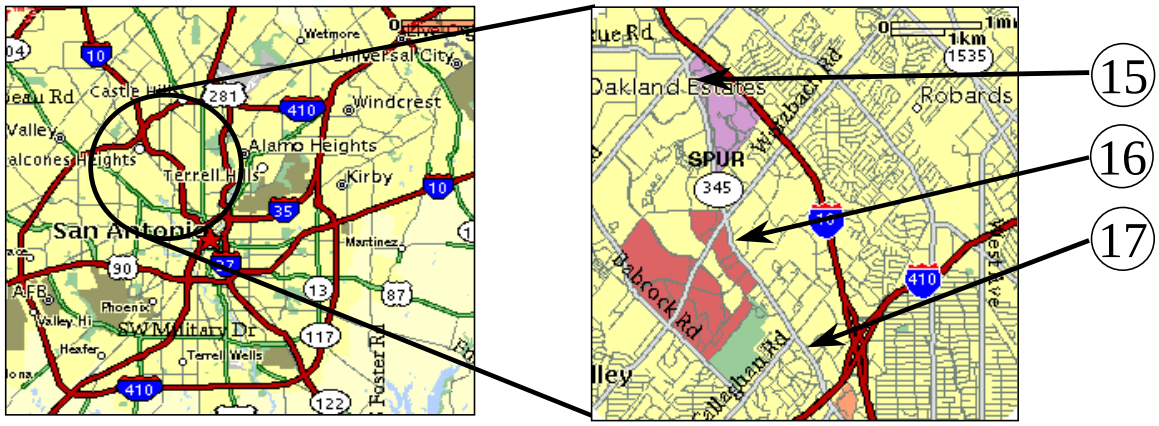

Figure 3.5 – Arterial AVI Data Collection Route: Fredericksburg Rd.
(source: http://www.mapquest.com/**)**

Data collection on Fredericksburg Road was performed to evaluate the accuracy of AVI travel time estimates on an arterial with slower traffic speeds than those found on the AVI section of I-35/410. This section of Fredericksburg Road is of significance because it serves as a separate test area in San Antonio's MMDI program. Nicknamed the "Medical Corridor" because of its proximity to the South Texas Medical Center, the traffic corridor defined by Fredericksburg Rd. and I-10 run parallel to one another for a length of roughly four miles. In the event of heavy

congestion on I-10, the Medical Corridor will serve as a potential traffic diversion route from just north of I-410 to the Fredericksburg Rd./I-10 interchange. The AVI sites on the Medical Corridor (sites 15, 16 and 17) will supply vital information to Transguide incident management officials regarding the traffic flow characteristics on Fredericksburg Rd. in the event of an incident on I-10. Transguide officials will use the AVI information to determine if diverting traffic to Fredericksburg will improve overall throughput in the Medical Corridor in the event of a congestion-causing incident on I-10.

Originally the driving schedule for data collection on Fredericksburg was to match that of I-35/410. Owing to equipment difficulties, however, the collection of data was cut short somewhat. Data collection did not begin until the PM peak on 6/9/98, continuing through 6/10/98 AM, midday, and PM peaks and off-peak, and ending after the AM peak on 6/11/98. During the 6/9/98 PM runs, all signalized intersections were marked using the GPS keypad, and all AVI reader locations were marked along with signalized intersections on 6/10/98 and 6/11/98.

3.3.3 Tabular Summary of June Data Collection

A summary of June GPS data collection trips by Route, Date, Time-of-Day and Direction is provided in Table 3.6:

Table 3.6 – June 1998 GPS Data Collection Summary

		Northbound Trip Breakdown			Southbound Trip Breakdown			Total
Route	Date	AM	Midday	PM	AM	Midday	PM	Trips
I-35/410 & I-37	6/9/98	5	6	4	5	6	4	30
Fredericksburg	6/9/98	0	0	5	0	0	4	9
I-35/410 & I-37	6/10/98	3	4	4	3	3	4	21
Fredericksburg	6/10/98	9	7	4	8	7	3	38
I-35/410 & I-37	6/11/98	3	3	3	3	3	3	18
Fredericksburg	6/11/98	6	0	0	6	0	0	12
Blanco	6/12/98	2	2	2	2	2	2	12
Jones Maltsberger	6/12/98	1	1	2	1	1	1	7
Thousand Oaks	6/12/98	0 (lost)	1	3	0 (lost)	1	3	8
Nacogdoches	6/12/98	0 (lost)	1	3	0 (lost)	1	3	8
								163

With a sizeable GPS data set compiled for both arterial and freeway AVI links, evaluations on the AVI equipment functionality could be performed using the GPS units as an independent source of measurement.

3.4 Summary

In this chapter, the accuracy of a GPS measuring device was tested, and a summary of test runs performed on AVI links was presented.

Given the GPS unit's high repeatability and spatial accuracy demonstrated by the RMSE and correlation analyses, it was concluded that the Trimble Placer 400 GPS unit was a suitable benchmark for measuring AVI reliability and accuracy. Establishing the GPS unit as a benchmark was a prerequisite for assessing the reliability and accuracy of San Antonio's AVI system using a single probe vehicle. The AVI accuracy and reliability study is presented in Chapter 4.